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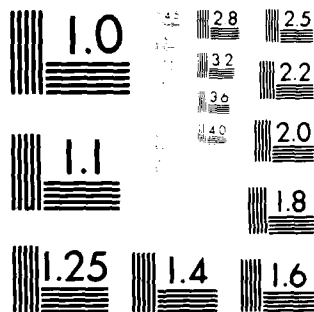
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ENGINEERING FACILITIES TECHNICAL MEMORANDUM 5

THE PRODUCTION OF PRINTED CIRCUIT BOARDS,
PHOTO-ANODISED AND SCREEN PRINTED INSTRUMENT PANELS

B.F. PORRITT

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(6) THE PRODUCTION OF PRINTED CIRCUIT BOARDS,
PHOTO-ANODISED AND SCREEN PRINTED INSTRUMENT PANELS.

(10) B.F. PORRITT

SUMMARY

This note explains in detail, the manufacturing procedures adopted at A.R.L. for the production of single-sided, double-sided and through-hole plated printed circuit boards and anodised, photo-etched and screen-printed instrument panels.

All manufacturing procedures, some original, were adopted only after extensive investigation and experimentation as to their compatibility with the small batch requirements of A.R.L. The principal reason for the publication of this Tech. Memo. is for the use of personnel within A.R.L., However, the information contained in this memorandum may be of use to others intending to set up their own facilities for the manufacture of printed circuit boards.

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1. INTRODUCTION

In 1965 the Instrumentation Group of Aerodynamics Division set up a small facility to manufacture prototype printed circuit boards for its own use. The method used was the employment of a Rank-Xerox copier to deposit a chemical resist on the surface of copper clad laminate. This proved satisfactory for very small batches but had the main disadvantage of the extreme care needed in avoiding movement once the transfer material came in contact with the image formed by the toner powder on the selenium plate - particularly when making double-sided boards.

By 1969 increasing requests for boards by other divisions of A.R.L. necessitated the board production facility to be taken over by Engineering Facilities Division. A more conventional production technique, the photo-resist-etch method was then adopted. Teething troubles were many but by experimentation reliable yields were obtained once the fundamental problems caused by dust, excessive light and incorrect timing of manufacturing stages were overcome.

By extending the etching facilities to include photo-anodising, it became possible to manufacture photo-etched anodised panels for electronic assemblies.

Through-hole plated printed circuit boards presented a much greater challenge. Gold was initially tried as the plating medium but proved to be too expensive and unreliable to provide high successful yields. Copper, plated with tin-lead gave much better results.

In developing the processes now used at A.R.L. it was found that printed-circuit manufacturing firms were reluctant to divulge information. It was also found that photo-etch suppliers were not sufficiently versed on the techniques required. It was therefore necessary to experiment with information gained from publications particularly when developing the through-hole process.

Because of natural staff changes in the board manufacturing area, it was imperative to keep accurate notes of the processes used, as small departures from the correct technique will cause wastage of time and materials. It is from these notes that this report has been prepared in the hope that it may be of assistance in an area where information is very difficult to obtain.

The manufacturing techniques outlined in this report are continuously being modified and improved and the processes in this report apply at the date of publication.

2. THE WORK AREA

Experience has shown that the work area plays a major part in successful photo-etching. Several important requirements are to be satisfied and are outlined in the following paragraphs.

2.1 Siting of the Work Area

It is desirable that the work area be situated at ground level to avoid seepage of spillages to rooms below.

2.2 Floor and Bench Coverings

Floor and bench coverings should be of acid resistant P.V.C. to prevent damage to work surfaces and facilitate easy cleaning.

2.3 Lighting

The work area should be illuminated by a safelight system consisting of orange fluorescent Philips TL 40W/16 lamps. Daylight should be kept to a minimum and windows should be covered with Kodagraph Sheeting, Orange. The extent to which ultraviolet radiation is minimised depends upon whether photo-resisted stock is to be left uncovered for an appreciable length of time.

2.4 Ventilation

Adequate ventilation is required not only to remove fumes, but to avoid dust carrying draughts which affect work being processed.

Tank ventilation is best achieved by a system which draws off fumes across the surface of the tanks rather than up past the face of the operator and through a canopy. (Ref fig. 1) E.P.A. specifications require a capacity of 3.3 m/s per metre of tank surface area, and the velocity in the duct should not exceed 12.7 m/s (metal duct) or 15 m/s (plastic duct). Scrubbers should be fitted in the exhaust line and exhaust fumes should be 90% to 95% clear. A general view of the workshop area is shown in Fig. 2.

2.5 Drainage

Drains for waste chemicals must conform to M.M.B.W. requirements, (acid resistant, with neutralizing tanks etc.). Information is best obtained from the M.M.B.W. prior to installation.

2.6 Spray Rinsing

Water spray rinsing tanks with foot operated spray heads are necessary. The spray heads must give a fine, strong spray capable of thoroughly cleansing through the drilled holes of printed circuit boards.

2.7 Workpiece Agitation

Agitation of the workpiece in the bath is essential for successful through-hole plating. Air agitation is not satisfactory because the solutions must wash through the holes. Agitation is best achieved by mechanical movement of the workpiece in the plating bath.

2.8 Electrical Isolation

For safety, it is advisable to have an isolation switch fitted outside the work-area entrance (power points only) so that in an emergency, power can be isolated without the work-area having to be entered.

2.9 Additional Safety Measures

When preparing a diluted acid mix it is essential to add the acid to the water as the reverse procedure can be dangerous.

Additional safety measures must be tailored with a view to the chemicals being used. Of particular importance is the presence of:-

- Cyanide antidote kit.
- Emergency shower.
- Poisons chart.
- Poisons Information Centre phone number.

2.10 Personal Protection

Measures to protect personnel must take the form of provision of:-

- Acid-proof coats and trousers.
- Safety glasses.
- Acid-resistant gloves.
- Acid-resistant safety shoes.

2.11 Handling of Workpieces

For successful work-yield, it is essential that fingermarks be kept off workpieces. Thus it is recommended that disposable polythene gloves be provided for the operator.

2.12 Production Flow

To produce reasonable quantities of good quality P.C. boards it is necessary to install an "in line" system of production flow; not only to reduce operator movement but to minimize oxidation due to time delay between steps. Water rinse tanks must be in sequence to minimize chemical carry over. See Figs 3, 4 and 5.

3. PHOTOGRAPHY

The camera used by A.R.L. for photo etching requirements is a locally produced "Neograph" model 510 horizontal, dark room, motorised camera which can be set very accurately for reduction to 1:4 and enlargements to 2.75:1. Maximum film size is 61cm x 51cm and the maximum copy size 76cm x 61cm.

Particular attention is paid to cleanliness in the area in which the camera is housed as dust specks can be reproduced on film causing tracks to be short circuited. (Refer Figs 6, 7 & 8).

3.1 Neograph Horizontal Dark-room Camera Model C 510

The camera is equipped with:-

1. A vacuum frame copyboard which should be kept free dust and dirt.
2. A position indicating counter which permits accurate focussing for standard reductions or enlargements.
3. Control console incorporating:-
 - (i) A ten step speed control for carriage movements.
 - (ii) A carriage locking switch with indicator light. This switch prevents inadvertent movement of the carriage from the required setting.
 - (iii) Exposure control with 'Stag' electromechanical time operating solenoid actuated shutters or a flash-lamp with a three position switch (a separate switch is fitted for manual control). The timer range is 0 to 6 seconds or 0 to 6 minutes.
 - (iv) A motorised control for focussing from full aperture to f22 (the main exposure position). Other aperture settings can be made manually at the camera front.
 - (v) An ON/OFF switch with indicator for copyboard lighting.
 - (vi) An ON/OFF switch with indicator for operating the vacuum pump (there is also a switch for this function mounted at the copyboard).

3.2 Film

3.2.1 Ortho Film

Ortho film is used for normal film work under red safelight.

The emulsion side, discernable because it appears lighter in colour, should face the camera. Exposure times depend on the reduction or enlargement required. A common practice is to use a standard exposure time of 30 seconds and develop by eye.

3.2.2 Ortho & Pan Film

Ortho & Pan films are used for photographing red and blue artwork. Pan film has a serrated edge in one corner as an aid to determining the emulsion side.

3.3 Photography Procedure

1. Locate the master on the copyboard with track side in the horizontal position facing up. Turn on the copyboard vacuum and open the valve on the side of the frame for maximum vacuum. Locate the copyboard vertically.
DO NOT OPEN IN THIS POSITION
2. Position the lamps to give uniform illumination of master.
3. Unlock and lower the rear of the camera (use sighting hole) to check for centering of the master.
4. Raise the rear of the camera and lock.
5. Set the copyboard and camera position in accordance with the following table. Move up to required position in one direction only to avoid inaccuracies caused by backlash in the gearing. The lens and copyboard position settings as follows applies to the A.R.L. camera only.

Settings for Standard Reductions

| <u>Reduction</u> | <u>Lens Position</u> | <u>Copyboard Position</u> |
|------------------|----------------------|---------------------------|
| 1:1 | 3645 | 7250 |
| 2:1 | 2740 | 8212 |
| 3:1 | 2433 | 9673 |
| 4:1 | 2272 | 11409 |

Settings for Standard Enlargements

| <u>Enlargement</u> | <u>Lens Position</u> | <u>Copyboard Position</u> |
|--------------------|----------------------|---------------------------|
| 1:1.5 | 4322 | 7484 |
| 1:2 | 5475 | 8158 |
| 1:2.5 | 5721 | 8353 |

6. Under safelight - red for ortho film

Place the film on filmboard emulsion facing up with stops set for the correct film size and turn on the vacuum pump. Close the rear of the camera.

7. Set the timer for 30 seconds exposure at f22.
8. Turn copy lights on.
9. Press shutter button.
10. When exposure is complete, turn the copylights off and remove film for developing.

For red/blue artwork steps 1 to 5 are appropriate.

Film used is pan film under a green safelight & ortho film under red safelight. With blue filter in place, emulsion side must be up (Ortho Film).

With red filter in place, emulsion side must be down (Pan Film).

Filters and Exposure Times for Pan Film

| Reduction | Bishop Tape | | Chartpak Tape | |
|-----------|----------------|-------------|---------------|-------------|
| | Red Filter | Blue Filter | Red Filter | Blue Filter |
| | NO. 29 Time | NO. 47 | 25 Time | 38 |
| 4:1 | 7 Sec | 2 min | 7 secs | 2 min |
| 3:1 | 7 Sec | 2 min | 7 secs | 2 min |
| 2:1 | 7 Sec | 2 min | 7 secs | 2 min |
| 1:1 | 7 Sec | 2 min | 7 secs | 2 min |

Aperture at f22

Film - Kodalith Ester Base Pan Film #2568 & Kodalith (Ortho Film)

Filter - Kodak Wratten gelatin.

3.4 Contact Reversal Photography

Film

1. Drop camera filmboard to horizontal position.
2. Place film with negative on top.
3. Switch on flashlamps. Expose for 30 seconds.

4. MANUFACTURE OF SINGLE-SIDED AND NON THROUGH-HOLE PLATED DOUBLE SIDED PRINTED CIRCUIT BOARDS

The process of manufacture of non through-hole plated P.C. boards is relatively simple compared with that for through-hole plating, but problems can occur due to lack of attention to detail.

4.1 Single Sided Boards - Method

1. Clean copper clad laminate with steel wool or 'Scotch Brite' pad and C.D.70 cleaner deoxidiser (1 part C.D.70 to 20 parts water) in a P.V.C. tray. (See Appendix 1).
2. Rinse thoroughly in water.
3. Dip laminate in KPR photo-resist being careful to obtain an even film. (See Appendix 2).
4. Bake work in oven at 80 degrees Celsius for 2 to 3 minutes and place in a dark box to cool.
5. Place a transparency of the track pattern onto the resisted board. Expose in the vacuum frame U.V. light box for 210 seconds. (Where possible, it is desirable to place emulsion side of film in contact with the board).
6. Develop the board in a trichlorethylene vapour bath until the track pattern is clear.
7. Run board through the FSL22 etching machine to remove all unresisted copper. (See Appendix 3).
8. Strip resist from the board by immersing in 533 stripper and gently rubbing with a nylon brush.
9. Tin-plate remaining copper tracks as described in appendix 4.
10. Gold plate the teeth (if any) as described in appendix 5.
11. Drill board as outlined in 8.1 and 8.2.

NOTE: If using Dupont Dry Film Resist 211R, (as described in the the section on through-hole plating), omit steps 3 and 4 and for step 6 use Dupont D2000 developer instead of trichlorethylene vapour.

4.2 Double Sided Boards - Method

The method for double sided boards is identical to that for single sided boards except that double sided clad laminate is used and photo-exposure is as outlined in 4.2.1.

4.2.1 Preparation of Negatives for Double Sided Boards

The negatives of both track patterns are placed together using a strip of PC board offcut as a spacer and aligned for correct hole registration. They are then taped together over the top edges to fix the negative locations. The double-sided laminate is then placed in between both negatives and exposed as in step 5 of the preceding method. The board is then processed as in steps 6 through 11 as for single sided boards.

5. THE MANUFACTURE OF THROUGH-HOLE PLATED PRINTED CIRCUIT BOARDS

Although on first appraisal it may appear to be a very complex procedure, through-hole plating of printed circuit boards can be successfully accomplished by strict adherence to the times and sequence of operations. It follows therefore that equal care must be taken in the preparation of the required solutions.

5.1 Baths Required

(N.B. Tanks should be of rigid P.V.C.)

1. Ammonium persulphate solution 100 gm/L.

2. Sulphuric acid 10% (A.R. GRADE).

Sulphuric acid (98%) - 1.5 L (A.R. GRADE)
Water - 13.5 L

3. Hydrochloric acid 20% (A.R. GRADE).

Hydrochloric acid (32%) - 3 L (A.R. GRADE)
Water - 12 L

4. PCB 30 Activator

Water (distilled) - 8.8 L
Hydrochloric acid (32%) - 4.4 L (A.R. GRADE)
PCB 30 - 1.8 L

5. Accelerator (Dynachem conditioner 101)

Water - 12 L
101 conditioner - 3 L

6. PCB 50 Electroless Copper

Mix in the following order:-

Water (distilled) - 8 L
PCB 50 "A" - 1 L
PCB 50 "C" - 100 mL
PCB 50 "B" - 1 L
Water - 3 L

7. Copper plating bath

Water - 54 L
Copper sulphate - 5.5 kg
Sulphuric acid (98%) - 13.1 L
U.B.A.C. TM Brightener - 450 mL
Charcoal - 280 gm

A new solution must be treated with activated carbon or charcoal and then filtered into the plating bath.

8. Fluoroboric acid (10%) as a mild etch

Water - 13.5 L
Fluoroboric acid (40%) - 1.5 L

9. Tin-lead plating bath

'Solderex' solution - 90 L

10. Copper Etchant

Mix in the following order:-

Udylite solution A - 6.75 L
Water - 5.5 L
Udylite solution B - 1.25 L

(To rejuvenate, remove 1L from the bath and add 1L of solution A).

11. Solder Strip

Fluoroboric acid (40%) - 250 mL
Hydrogen peroxide (30%) - 50 mL
Water - 700 mL.

5.2 Method

1. Make a drilling template using copper clad plate and the negatives of the artwork.
2. Make positives from the above negatives and black out all holes.
3. From the above positives, make another set of negatives (with holes absent) and from these make semi-transparent positives using 'Colour-Key'.
4. Drill the template using the high-speed Acro drill.
5. Deburr using wet and dry paper.
It is now essential to ensure the board is not contaminated by fingerprints.
6. Etch board in ammonium persulphate for 2 minutes.
7. Spray rinse.
8. Immerse in 10% sulphuric acid for 2 minutes.
9. Spray rinse.
10. Immerse in 20% hydrochloric acid for 2 minutes to deoxidise copper and treat fibreglass.
11. Activate fibreglass in PCB 30 activator for 6-10 minutes.

12. Spray rinse.
13. Immerse in accelerator (Dynachem 101) for 3-6 minutes.
14. Spray rinse.
15. Immerse in electroless copper PCB 50 for 10 minutes to provide a key for plating.
16. Spray rinse.
17. Electroplate in copper bath for 15 minutes at 22 mA per sq.cm. (1 amp per 7 sq.ins.) (Appendix 7) ensuring that power supply is turned on prior to immersion of work in the bath.
18. Clean with wet and dry paper.
19. Rinse and dry.
20. Apply dry film resist. (Appendix 2).
21. Expose in light box using 'colour key' positives as the mask.
22. Develop the board.
23. Check for errors and touch up. Spots of unwanted photo resist may be removed carefully with a scalpel. Spots of missing photo resist may be replaced with a small brush using a rapid air drying resist.
24. Electroplate in copper bath for 30 minutes at 11 mA per sq.cm. (1 amp per 14 sq.ins.) (Appendix 7).
25. Rinse.
26. Immerse in 10% fluoroboric acid to activate for fluoroboric solder bath.
27. Spray rinse.
28. Electroplate in tin-lead bath for 10 minutes at 11 mA per sq.cm. (1 amp per 14 sq.ins.) (Appendix 8).
29. Spray rinse.
30. Dry thoroughly.
31. Remove resist with 533 stripper.
32. Inspect tracks and touch up with solder if necessary.
33. Etch in copper etchant for 5 minutes.
34. Rinse and dry.
35. Clean solder with steel wool.
36. Reflow lead-tin plating. (Appendix 9).
37. Trim board roughly.
38. Strip solder from teeth using the solder-strip solution.
39. Gold plate the teeth. (Appendix 5).
40. Trim the board to the dimensions required.

6. ANODISING AND DYEING OF ALUMINIUM

In order to obtain uniform dyeings and surface finishes careful pretreatment of the aluminium is essential.

Material which is not thoroughly cleansed will anodise unevenly and is a frequent cause of defective dyeings. Surface defects are accentuated after anodising, therefore the required finish should be attained prior to commencement of the anodising process.

6.1 Anodising

6.1.1 Baths Required

(N.B. Tanks should be of rigid P.V.C.)

1. Trichlorethylene vapour bath for resist development (if photo-etching is required).
2. 4.5 kg of caustic soda dissolved in 90 L of water for descaling of aluminium.
3. 50% solution of nitric acid to desmut aluminium. 45 L of Nitric acid (63%) added to 45 L of water.
4. Anodising bath of sulphuric acid solution consisting of 14 L of sulphuric acid (98%) added to 78 L of water. Bath to have lead-lining as cathode.

6.1.2 Equipment Required

'VIM' household abrasive powder.
Steel wool.
Aluminium wire (16 gauge).
D.C. Power Supply 100 amp, 20 volt.

6.1.3 Method

1. Select an oversize piece of aluminium.
2. Using water, 'VIM' and emery cloth, prepare the surface by rubbing in longitudinal strokes.
3. Repeat (2) with a finer grade of emery cloth and then steel wool to obtain a smooth even finish.
4. Rinse work thoroughly.
5. Attach two pieces of aluminium wire around workpiece such that the workpiece can be immersed in subsequent baths.

6. Degrease and lightly etch the work by immersing in the caustic soda bath for 10 to 15 minutes. Do not immerse long enough for the solution to dissolve the suspension wires.
7. Rinse thoroughly in water.
8. Immerse work in the nitric acid solution for 2-3 minutes to desmut the surface.
9. Immerse work in the anodising bath and connect negative terminal to the lead tank lining and the positive terminal to the workpiece.
10. Set current density to 16 mA per sq.cm. (15 amp per sq.ft.) of workpiece and anodise for 40 minutes. For better anodising the current can be reduced but the anodising time must be increased proportionately. Ensure that anodising is not continued past the times indicated. Oil-free-air agitation is recommended.
11. Rinse thoroughly in clean cold water to lay the foundation for good sealing thus prolonging the life of subsequent dye solutions.

The work is now ready for dyeing and must not be fingermarked.

If dyeing is not required, the anodic coating may now be sealed by immersion in boiling water for 20 minutes.

Sealing closes the pores of the anodic coating rendering it impervious to finger marks and greasy stains.

NOTE: Once sealed, aluminium cannot be further dyed.

6.2 Dyeing of Anodised Aluminium

Dyeing is used either to obtain a uniform coloured finish or in preparation for photo-anodising of desired artwork.

6.2.1 General Remarks

Aluminium dyestuffs have a maximum affinity for anodic film at temperatures between 55 to 65 degrees Celsius. Most colours can be dyed at room temperature, but stronger concentrations will be necessary to produce shades equivalent to those dyed at 60 degrees Celsius. However, it should be noted that cold dyed colours are easier to strip and should be used in multi-coloured work. After dyeing rinse briefly and seal immediately.

6.2.2 Dyeing Times

Dyeing is carried out by immersing the anodised material for 5 to 15 minutes except when dyeing deep-black when 30 minutes will be required. Durations exceeding 30 minutes have no advantage.

6.2.3 Batch Uniformity

If several panels are to be dyed the same colour, better uniformity can be achieved by anodising and dyeing the workpieces in the same bath simultaneously to eliminate colour variations due to variables such as electrolyte temperature, current density and duration.

6.2.4 Dye Bath Preparation

Information regarding quantities and method of preparation can be obtained from literature provided by the dyestuff suppliers.

Sandoz Aust. P/L.
675-685 Warrigal Rd.
Chadstone. Vic.

6.2.5 Dye Deterioration

Some dyes are more difficult to use than others, in particular, 601 Green GLW and Fast Grey 3LW. These dyes deteriorate in the mixed solution when exposed to air.

The addition of a mixture of 1mL of acetic acid and 8gm of sodium acetate to each litre of dye solution will act as a neutraliser and assist bath life.

6.3 Photo Etching of Anodised Aluminium

This process is required when artwork or lettering is to be included on anodised panels.

6.3.1 Method

1. Prepare photographic negative or positives of artwork as described in the section on photography.
NOTE: Black areas on transparencies will correspond to portions of dye which are to be removed.
2. Anodise the panel as described previously. Dye the aluminium immediately to ensure that the dye acts as a pore filling medium.
3. Rinse thoroughly and allow the surface to dry.
4. Coat the surface by dipping into KPR photoresist and allow it to dry.

5. Expose the surface using the photograph of artwork as described in the section of 'Manufacture of Printed Circuit Boards'.
6. Develop the work in trichlorethylene vapour bath by holding work with 'battery clips', until image is uniform and visible.
CAUTION the vapour bath is hot.
7. Immerse work in caustic soda solution to dissolve dye whilst rubbing softly with rubber gloves until image is clear. Do not over-rub otherwise image will be ruined.
8. Rinse.
9. If desired, strip the resist using resist stripper and nylon brush. Be careful not to immerse in stripper for too long otherwise the dye will be attacked.
10. Rinse, dry and rub work down with liquid paraffin until a satisfactory result is achieved.
11. This method removes the exposed anodised layer therefore where multi colours are required the process must be repeated using suitable photographs to mask the area required.

6.4 White Satin Etch for Aluminium

This process produces an excellent background for silk screening.

The purest aluminium should be used.

6.4.1 Solutions Required

(N.B. Tanks should be of rigid P.V.C.)

WARNING:- THE ADDITION OF SULPHURIC ACID TO SODIUM FLUORIDE IN SOLUTION 'A' COULD PRODUCE HYDROFLUORIC ACID. THIS ACID IS EXTREMELY DANGEROUS. DIRECT CONTACT MUST BE AVOIDED AND ADEQUATE VENTILATION MUST BE PROVIDED. IF ACCIDENTAL CONTACT DOES OCCUR, WASH THE AFFECTED AREA IN RUNNING WATER FOR AT LEAST 20 MINUTES AND SEEK MEDICAL ADVICE.
USE PROTECTIVE CLOTHING AND SAFETY GLASSES.

SOLUTION 'A' - 1. 90 ml of cold water.

2. Carefully and slowly add 15ml of concentrated sulphuric acid.
3. Add 10gm of sodium fluoride.

SOLUTION 'B' - 1. 90ml of cold water.

2. Add 10gm ammonium hydrogen bi-fluoride.
3. Add a pinch of copper sulphate.

6.4.2 Method

1. Prepare a bath of 5% to 15% caustic soda solution.
2. Prepare a bath of 50% nitric acid.
3. Immerse aluminium in the caustic soda solution.
4. Rinse thoroughly in water.
5. Immerse in solution 'A' for 1 minute.
6. Rinse thoroughly in water.
7. Immerse in solution 'B' for 1 minute.
8. Rinse in hot water.
9. Immerse in 50% nitric acid bath for 1 minute.
10. Rinse in hot water.

7. SCREEN PRINTING

An alternative method of producing instrument panels and printed circuit boards using a Printers Ink Resist. Suitable for large quantities where fineness of definition is not important.

7.1 Screen Printing Requirements

1. Suitable sized screen of polyester or nylon mesh. (Polyester more suitable for wear resistance and fine detail).
2. Polyester degreaser.
3. 'Ajax' bleach for roughening screen to aid film adhesion.
4. Water soluble film - 'Five Star' or 'Auto Star'. (Five Star best for fine detail).
5. Hydrogen peroxide (5% solution) for hardening film.
6. Suitable water spray to clear open areas of screen.
7. Formica backing board.
8. Printing inks.
9. Soluble screen filler.
10. Squeegee.
11. Stencil strip.

7.2 Applying the Stencil

1. Degrease screen with a suitable screen degreasing solution. e.g. 10% caustic soda solution.
2. Place a positive master film wrong way up on the backing side of the stencil film.
3. Place in vacuum frame of the light-box and expose for 90 seconds.
4. Immerse stencil film for 1 minute in 'Autotype' or a 5% solution of hydrogen peroxide to harden the emulsion.
5. Develop the stencil film with warm water spray, visually checking that overdeveloping has not occurred.
6. Place stencil film on a flat 'Formica' backing and place under the screen (emulsion side to the screen).

Ensure that the screen is wet.

7. To tighten the film against the screen, build up under the formica backing with newspapers.
8. Carefully blot the surface of the screen with absorbent paper to make the emulsion adhere.
9. Inspect the image for transparency of the screen. If scum is evident, wash with running water whilst holding the Formica backing against the film to prevent movement.
10. Gently air-dry in a warm atmosphere. Too much heat or excessively long drying may cause the film to adhere to the protective mylar backing on the stencil film.
11. Remove the protective mylar backing sheet from the stencil film smoothly and carefully.
12. Areas of the screen not required can be blocked out with 'Quickset V77' water soluble screen filler.

7.3 Transferring the Image to the Work

1. Place the work in position under the screen ensuring that the screen is approximately 4mm above the work so that it breaks contact immediately pressure is removed.
2. Pour a suitable amount of the desired colour screen printing ink over the stencil.

3. Using a clean squeegee at an angle of 45 degrees draw it smoothly over the screen surface with enough pressure to make good contact with the work. Best results are obtained if only one firm sweep is used.
4. Now that the image has been transferred to the work, be careful not to smudge the wet ink, withdraw the work and allow it to dry.

7.4 Stripping the Stencil from the Screen

Use a Stencil Stripper to the manufacturers directions to strip the stencil.

Degrease the screen thoroughly with lacquer thinners before storing it.

8. DRILLING PRINTED CIRCUIT BOARDS USING 'ACRO' DRILL

The information given hereunder is to aid persons unfamiliar with the operation of the 'Acro' drilling machine currently in use at A.R.L. This drilling machine produces clean holes, without burrs, suitable for through-hole plating.

8.1 Optical Head Operation

1. Make template of boards to be drilled from double-sided copper-clad laminate.
2. Make up stack of boards with no more than 3 under the template.
3. Place stack of boards on drill table and set the clamping foot approx 1.6mm above the stack; lock foot.
4. Place tungsten carbide drill in the chuck making sure it is rotating centrally.
5. Wind the drill head up until it is just protruding through the guide bush, then back it off approximately 1 full turn of the handle, which is located at the rear of the machine.
6. Place stack of boards under the clamping foot, making sure the drill will not touch the boards, then depress the foot pedal; drill will then rise through the table. Set depth of drill while in this position (approximately 1.6mm higher than the stack). Depth adjustment is on the side of drill spindle.
7. Set line switch to 'ON' position.
8. Set drill-head switch to 'AUTO'.
9. Set stylus switch to 'OPTIC'.

10. Set spindle controller to drill speed relative to size of drill (e.g. smaller the drill, the higher the speed). Work in a range of from 30,000 to 40,000 R.P.M.

8.2 Stylus Head Operation

1. Make template using H.S. drill of nominal size (e.g. 1mm) in pedestal drill.
2. Make stack of no more than 4 boards including template, drill and pin, same as for optical head procedure.
3. Set stack under stylus and adjust until approximately 0.8mm off stack. Move stack until a hole is directly under the stylus and adjust using the foot pedal (ensure that drill has been wound down) until the stylus comes into contact with the hole and then backs off.
4. While in the above position shift stack until a blank portion is over the stylus, then activate the foot pedal; if the stylus comes down but does not back off, stylus height is correct.
5. Set drill depth until the point of drill is approximately 3/4 deep into the board under the template; this is to ensure that the drill will not hit the point of the stylus.
6. Set optic switch to 'STYLUS'.
7. Set stylus delay switch (marked from 0 to 100 in seconds) half way, until the operator becomes familiar with the machine.

9. CONCLUSION

With continuous improvements and changes in materials and manufacturing processes it is accepted that some of the processes described in this memorandum could well become outdated. Should any radical changes occur in the processes described in the manufacture of printed circuit boards every endeavour will be made to update this document. Appendix 10 gives a list of suppliers recommended at the time of publication.

APPENDIX 1

CLEANERS, DEOXIDISERS, POLISHES

Actane 97

For cleaning copper alloys.

Concentration 90 g/L of water 97A

150 g/L of water 97B

Use at room temperature, immersion time 1-3 mins.

Method: Half fill P.V.C. tank with warm water 50-60 degrees C.

Dissolve the total amount of Actane 97B salts required to give a concentration of 150 g/litre of final operating solution. Then dissolve the total amount of Actane 97A required, with considerable agitation. Dilute to the final volume with either cold or warm water as required to bring the solution to an operating temperature of approx 21-24 degrees C.

Caution Actane 97A and Actane 97B are acid salts which contain powerful oxidizing agents and therefore, should not be allowed to come in contact with reducing agents, or any organic matter. The salts of Actane 97A and Actane 97B must not be mixed together as dry salts, only in solution as outlined under make-up. Also keep the salts away from heat, fire, or explosion hazards.

The final operating solution or salts should not be allowed to come in contact with the skin or eyes. In case of contact, flush the skin or eyes with plenty of water for at least 15 minutes; for eyes, obtain medical attention. Actane 97 solutions should be handled in the same manner as acid solutions. Keep containers tightly sealed and store in a dry location.

C.D. 70 For cleaning copper, use 1 part C.D. 70 with up to 10 parts water as required.

Phosbrite 159 For chemically polishing aluminium.

'Phosbrite 159' is supplied in ready to use solution.

Equipment: Molybdenum stabilized stainless steel (i.e. EN58J or type 316) tank welded correctly.

Heating: silica sheathed electric heaters (stainless steel clad heaters are unsuitable).

Method:

1. Preclean material if necessary with trichlorethylene vapour bath.
2. Immerse the aluminium in 'Phosbrite 159' at 95-105 degrees C for 30 sec. to 3 min. Gentle agitation should be used to prevent gas-streaking.
3. Rinse in slow running water, preferably heated to 40 degrees C max to aid removal of the viscous film.

A.1.a

4. To desmudge immerse in 50% by volume nitric acid for 30 seconds at room temperature. Alternatively use a 5% by volume solution of sulphuric acid to which is added 4 oz/gal (25 gm/L) chromic acid.
5. Rinse well in cold running water.

Note: While the Phosbrite bath is being worked nitric acid will be consumed. Additions of nitric acid must be made to maintain optimum polishing conditions.

WARNING: This solution is a mixture of concentrated acids and should be handled with great care. Wear goggles and protective clothing. Fume extraction is necessary.

'2.27' Used neat cleans copper.
Gives tarnish free finish when used 1 part '2.27' to 3 parts water.

'P.C.E.1' Cleaner and degreaser for aluminium and galvanised iron.
Mix with water to approx 1 part P.C.E.1 to 15 parts water.

'Resist Stripper 533' Used neat for removing K.P.R. from printed circuit boards.

'Solder Strip' Used neat to strip electro-plated solder from printed circuit boards.

Note: Oxidisation of copper and brass can be avoided by dipping the material into a weak solution (5 to 8% by volume) of hydrochloric acid and water, immediately after etching.

APPENDIX 2

RESISTS

While liquid resists have advantages in some instances, in the majority of cases dry film resists are superior for the following reasons:

| <u>Dry Film Resists</u> | <u>Liquid Resists</u> |
|--|---|
| Non Volatile | Volatile |
| Constant thickness | Varying thickness |
| Simple development | Hazardous development |
| Contrasting colors make inspection easier | Difficult inspection unless partly etched |
| Storage and handling easier because of protective film | Work storage and handling difficult because of lack of protection |
| No resist in drilled holes when through-hole plating | Extremely difficult to remove resist from drilled holes when through-hole plating |

Kodak Photo Resist (K.P.R.) is satisfactory for most applications when etching copper or anodised and dyed aluminium, but reference to Kodak booklets P79 and P131 should be made when etching steels and exotic materials.

Auto Positive Resist Type 3

Method

Apply resist by dipping.
Air dry for 10 minutes in dark.
Place in oven for 15 to 20 min at 80 to 90 degrees C.
Exposure by U.V. light (not too much).
Develop with Kodak Auto-positive Resist developer.

Note: Yellow safe lighting is essential for this process.

Dupont Dry Film Resist Type 211R

This resist is placed on the printed circuit board material by a laminating machine designed for this purpose.
Basically the film is rolled onto the board by rollers heated to 112 degrees C.
After the resisted board is exposed in the ultra-violet light box do not forget to remove the mylar protective backing on the resist before developing in Dupont Developer type 2000.

Various printers' resist inks are available for silk-screening, refer Appendix 10.

APPENDIX 3

ETCHANTS AND ETCHING

1. Aluminium Etchants

For normal etching of colour from anodised aluminium use a solution of 75mg sodium hydroxide (caustic soda) to 1 litre of water.

For deep etching aluminium without affecting the anodised surface use 1 volume of (38% concentrated) hydrochloric acid with 4 volumes of water. (This process allows the anodised surface to be used as a resist).

Another etchant for anodised aluminium consists of 50% hydrochloric acid, 47% water, and 3% nitric acid at 50 degrees C.

2. Copper Etchants

To prepare I.C.I. commercial liquid Ferric chloride solution:

50% liquid ferric chloride

40% water

10% hydrochloric acid

Specific gravity 1280

Best operating temperature 50-65 degrees C.

Preparation for Ferric Chloride powder mix:

Mix 6.36kg of powdered ferric chloride with 9.1L of boiling water.

Add 150 ml of hydrochloric acid.

To etch with Ammonium persulphate mix 10 kgms (22.5 lbs) to 136 litres (30 gallons) of water.

Note: Use P.V.C. containers for all of above etchants.

3. Etching Silver

Method

Use resists K.T.F.R. or K.M.E.R.

Degrease in vapour degreaser or other suitable means (Pumice where finish is not critical). Polishing grade buffing powder B.P.A. No. 1 where finish is critical.

Slightly etch with dilute nitric acid (50%) - Rinse in running water.

Dry resists at temperatures not over 82 degrees C for K.T.F.R. and not over 120 degrees C for K.M.E.R.

Postbake resist at 120 degrees C for at least 10 mins.

Etchant 1: 55% weight/volume solution of ferric nitrate used at 49 degrees C. This solution is made by adding 750mg of ferric nitrate crystals to 1 litre of water.

Etchant 2: A matt surface can be produced by using:

Chromium trioxide 40 gms.

Sulphuric acid (s.g. = 1.84) 20 mL.

Water 2000 ml.

A.3 a

Replacing Ferric chloride with Ammonium persulphate in Model F.S.L.22
Etching machine

Drain ferric chloride from machine.

Flush with warm water.

Add a 136 litre mix of ammonium persulphate.

Run machine for 30 minutes.

Drain and dump ammonium persulphate.

Flush with warm water.

Add a second 136 litre mix of ammonium persulphate and use this for etching.

Failure to follow this procedure results in the rubbers on the machine rollers swelling and becoming soft.

APPENDIX 4

IMMERSION PLATING TIN

Immersion plating tin is used to protect copper tracks of non through-hole plated boards against tarnish.

Bath Equipment

P.V.C. tank of sufficient dimensions to accommodate workpiece.

Chemicals Required

'Metex' Tin Salts - 426 gm

Hydrochloric Acid - 300 mL

'Macro Wet' - 80 mL

Bath Preparation

1. Place 2.8L of water into P.V.C. tank.
2. Carefully add hydrochloric acid.
3. Heat solution to 65 degrees Celsius.
4. Add 'Metex' tin salts and stir until dissolved.
5. Add 'Macro Wet'.
6. Add a further 1.4L of water and stir briefly.

Plating Method

With bath at 65 degrees Celsius, immerse work for 30 to 60 seconds.

APPENDIX 5

ELECTROPLATING GOLD

Gold is used to plate edge connector teeth of printed circuit boards and possibly copper tracks although the plating of copper tracks is not advised because of the gold being dissolved into solder joints causing them to become unreliable.

Chemicals Required

'Selrex Autronex C' Gold Solution.

WARNING: THIS SOLUTION CONTAINS CYANIDE. EXTREME CARE SHOULD BE TAKEN.

Equipment Required

1. A small plastic container to serve as the plating bath.
2. D.C. power supply.
3. Anodes of Platinised Titanium (Platanium) (Anode to cathode ratio of 4:1).

Method

1. Heat bath to 30 to 40 degrees Celsius.
2. Make electrical connections and dip work to be plated into bath.
3. Set current density at 6.5 to 13mA/cm² of area to be plated.

APPENDIX 6

ELECTRO PLATING TIN

Preparation:

Stannostar B.N.16000

Solution:

- | | |
|---|--------------------------|
| 1. Stannous sulphate - 40 gm/L | 40 gm/L (40 lbs/100 gal) |
| 2. Sulphuric acid - 140 gm/L | 7.6% by volume |
| 3. Part iv Brightener B.N.16004 - 10 mL/L | 1% by volume |
| 4. Part v Purifier B.N.16005 - 4 mL/L | 0.4% by volume |
| 5. Part vi Surface active agent B.N.16006 - 20 mL/L | 2% by volume |

Equipment:

Tank - P.V.C.

Anodes - Pure tin with a ratio of anode to cathode area of 2:1

Operating Conditions:

Smooth D.C. current - maximum ripple 5%.

Work rod agitation of at least 7.6 cm/s and up to 14 cm/s (air agitation is not recommended).

Temperature 18-30 degrees C.

Current density - cathode 11-44 mA per sq.cm. (10-40 amps/sq.ft.)

Current density - anode 11-22 mA per sq.cm. (10-20 amps/sq.ft.)

Filtration - desirably to be continuous.

At 22 mA per sq.cm. (20 amps/sq.ft.) deposition is 0.00254 mm in 2.4 mins.

Cleaning: Degrease work in organic solvent, rinse thoroughly and dip in 10% sulphuric acid.

Note: Use "live entry" when immersing work in plating bath.

Method.

The solution should preferably be made up in a spare tank which is 3/4 filled with water. The sulphuric acid is added first to the water which is kept stirred. Care should be taken at this stage as the solution heats up. Add the correct amount of stannous sulphate and stir until dissolved, the solution is then allowed to cool to room temperature. Add the B.N.16006 (Surface active agent) while stirring, then add water to required level and filter into plating tank. Finally add B.N.16004 (Brightener) and B.N.16005 (Purifier) while stirring. It is recommended to add half of the Brightener first, i.e. 5 mL/L, then add further amounts up to 10 mL/L according to practical observation as the brightness of the deposition lessens.

APPENDIX 7

ELECTROPLATING COPPER

This process is required to build up copper surfaces to adequate thicknesses on printed circuit boards undergoing the through-hole plating process.

Bath Equipment

Bath equipment should be constructed of P.V.C. and be of sufficient dimensions to accommodate the largest expected work.

Chemicals Required

Copper Sulphate
Sulphuric Acid (98%)
Chloride ions - usually present in tap water.
U.BAC-T.M. Brightener
Water

Bath Preparation

1. Measure a quantity of copper sulphate corresponding to 60 gm/L of water used.
2. Fill a suitable P.V.C. storage tank to two thirds of its capacity with water heated to approximately 60 degrees Celsius. Ensure that amount of water used is known.
3. Dissolve copper sulphate in the storage tank whilst stirring continuously.
4. Filter the solution into plating tank and allow to cool to the plating temperature (20 to 30 degrees Celsius).
5. Measure the sulphuric acid corresponding to 150mL per L of plating solution.
6. Whilst continuously stirring, carefully add the sulphuric acid to the plating solution.
7. Measure out U.BAC-T.M. Brightener corresponding to 0.25% of plating solution volume.
8. Add Brightener to plating solution. (More brightener may be required to compensate for absorption by tank linings and filter bags).
9. Treat with activated carbon. Refer 5.1, 7.

Additional Plating Equipment

Power Supply - 100 amps D.C.
Anodes - phosphorised copper
Cathode - workpiece to be plated.
Anode to Cathode area ratio - 2:1.

A.7a

Plating Method

1. Ensure that bath temperature lies between 20 and 30 degrees Celsius.
2. Ensure that plating solution is filtered at the rate of at least 1 bath volume per hour.
3. Set power supply current corresponding to approximately 22 mA per sq.cm. (1 amp per 7 sq.ins.) of area to be plated.
4. With the current on, attach the negative electrode to the workpiece and immerse in plating bath for 15 minutes.

NOTE: Immersion of the workpiece with the power supply on is important to prevent the plating solution from attacking the thin copper plating already on the workpiece.

5. Activate mechanical agitation of the workpiece.

APPENDIX 8

ELECTROPLATING LEAD-TIN (SOLDER)

Electroplating lead-tin is used (in conjunction with solder reflow) for providing a protective medium to copper tracks of P.C. boards in etching during the through-hole process and a protective bright surface to subsequently prevent copper tracks from tarnishing.

Solution

'Solderex' available from Oxymetal Industries P/L.

Method

Method, equipment and operating conditions in this plating process are almost identical to those used in copper plating (Appendix 5) except that anodes used are made by fusing together commercial sticks of 60-40 lead-tin solder.

APPENDIX 9

REFLOWING 60-40 LEAD-TIN PLATING

Machines for this purpose are available commercially but they are both bulky and expensive.

The small batch requirements of A.R.L. prompted the in-house design and manufacture of a small, bench mounted reflow unit.

The unit consists of 6, infra-red heating elements with the following specification:

E8 Philips 220-250V, 1000W Quartz Infra-red lamp

The lamps are mounted in a polished aluminium casing and controlled by an automatic 0-60 second timer.

Method

1. Coat the lead-tin plated printed circuit board with Cromweld 965 flux.
2. Insert into heating area.
3. Set timer for 25 seconds and activate.
4. Whilst the solder is still setting, plunge the board into a bath of water.

NOTE

To remove reflowed solder from the teeth of printed circuit boards, use a neat solution of 'Solder Strip'.

APPENDIX 10

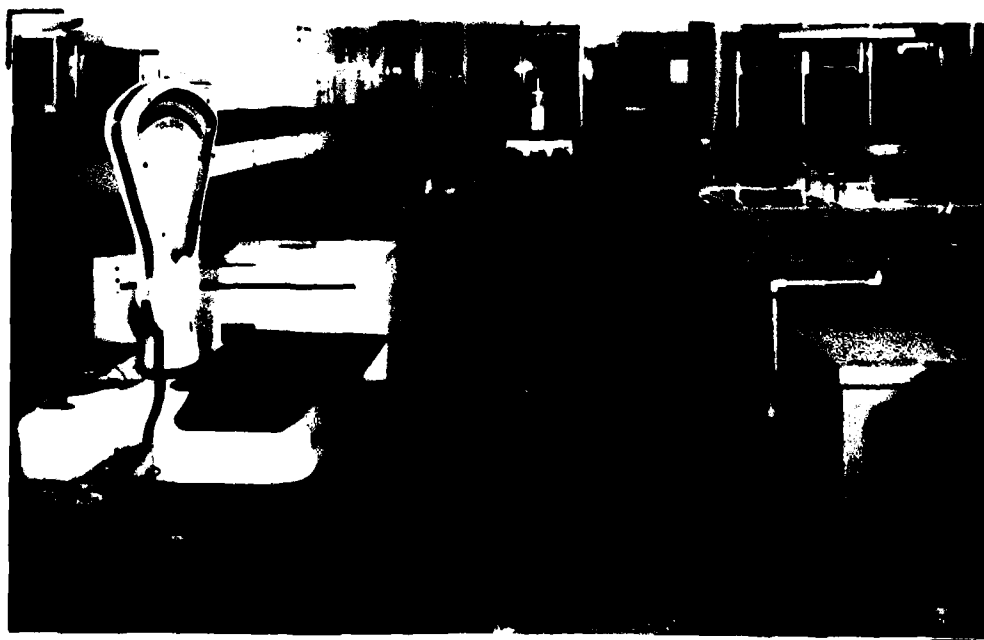
INDEX OF SUPPLIERS

| | |
|--------------------------------|--|
| Accelerator P.C.B.44 | Oxy Metal Industries (Australia) P/L |
| Actane | Robert Bryce and Co. |
| Autotype | Screen Printing Supplies P/L |
| Block out solution | Screen Printing Supplies |
| Brightener B.N.16004 | Oxy Metal Industries (Australia) P/L |
| Buffing Powders | Lawrence Smith and Canning |
| C.D.70 | Chemical Treatment and Coatings |
| Copper clad laminate | Menzies Electrical |
| | O.H. O'Brien P/L |
| Commweld 965 flux | C.I.G. |
| Dry film developer (Riston) | Dupont (Australia) Ltd. |
| Dry film resist (Riston) | Dupont (Australia) Ltd. |
| Dyes (Anodising) | Sandoz (Australia) P/L |
| Electroless copper P.C.B.50 | Oxy Metal Industries (Australia) P/L |
| Ferric chloride | I.C.I. (Australia) Ltd. |
| Film (Ortho, Pan) | Kodak (A'Asia) P/L |
| Film (screen printing stencil) | Screen Printing Supplies |
| Gold salts solutions | Oxy Metal Industries (Australia) P/L |
| Inks (screen printing) | Mander Kidd Printing Ink (Australia) P/L |
| Metex immersion tin salts | Oxy Metal Industries (Australia) P/L |
| Macro Wet | Oxy Metal Industries (Australia) P/L |
| Neograph horizontal camera | Neographics P/L |
| Oxytron P.C.B.27 | Oxy Metal Industries (Australia) P/L |
| Ortho film | Kodak (A'Asia) P/L |
| Phosbrite 159 | Allbright and Wilson (Australia) P/L |
| Quickset V77 screen filler | Screen Printers Supplies |
| Solderex | Oxy Metal Industries (Australia) P/L |
| Solder Strip | Oxy Metal Industries (Australia) P/L |
| Stencil Strip | Screen Printers Supplies |
| Stripper 533 | Chemical Treatment and Coatings |
| Surface active agent BN16006 | Oxy Metal Industries (Australia) P/L |
| Trichlorethylene | I.C.I. (Australia) Ltd. |
| 2.27 | Applied Chemicals P/L |
| Udylite M.U. etchant | Oxy Metal Industries (Australia) P/L |
| U.B.A.C. Brightener | Oxy Metal Industries (Australia) P/L |



Neg. No.0410-1

FIG.1 PROCESSING TANKS



Neg. No.0410-10

FIG.2 WORKSHOP AREA

To produce reasonable quantities of good quality P.C. boards it is necessary to install an "in line" system of production flow; not only to reduce operator movement but to minimize oxidation due to time delay between steps; and water rinse tanks in sequence to minimize chemical carry over.

Sequence of events - P.C. board production:

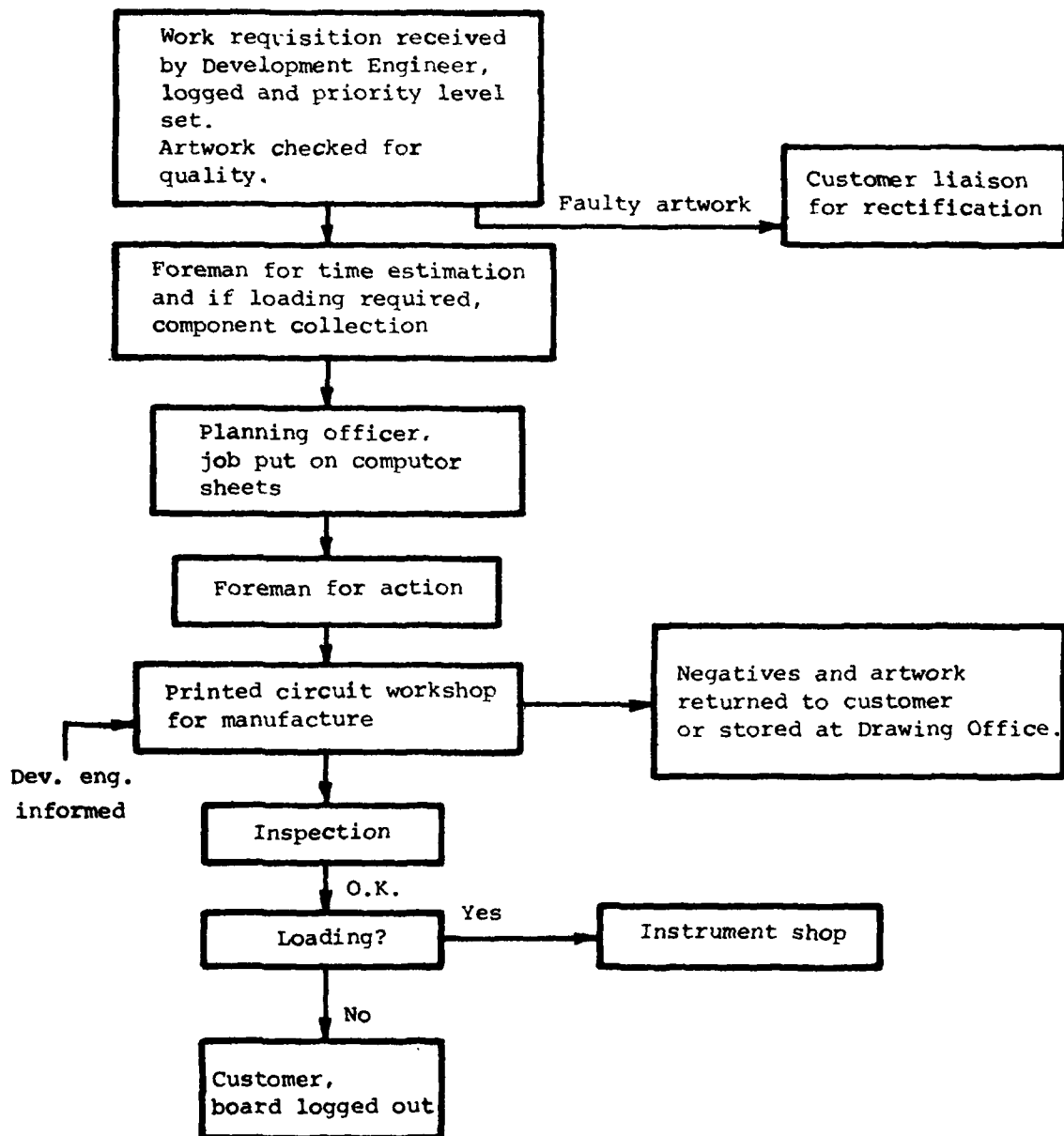


FIG.3 DIAGRAM OF PRODUCTION FLOW

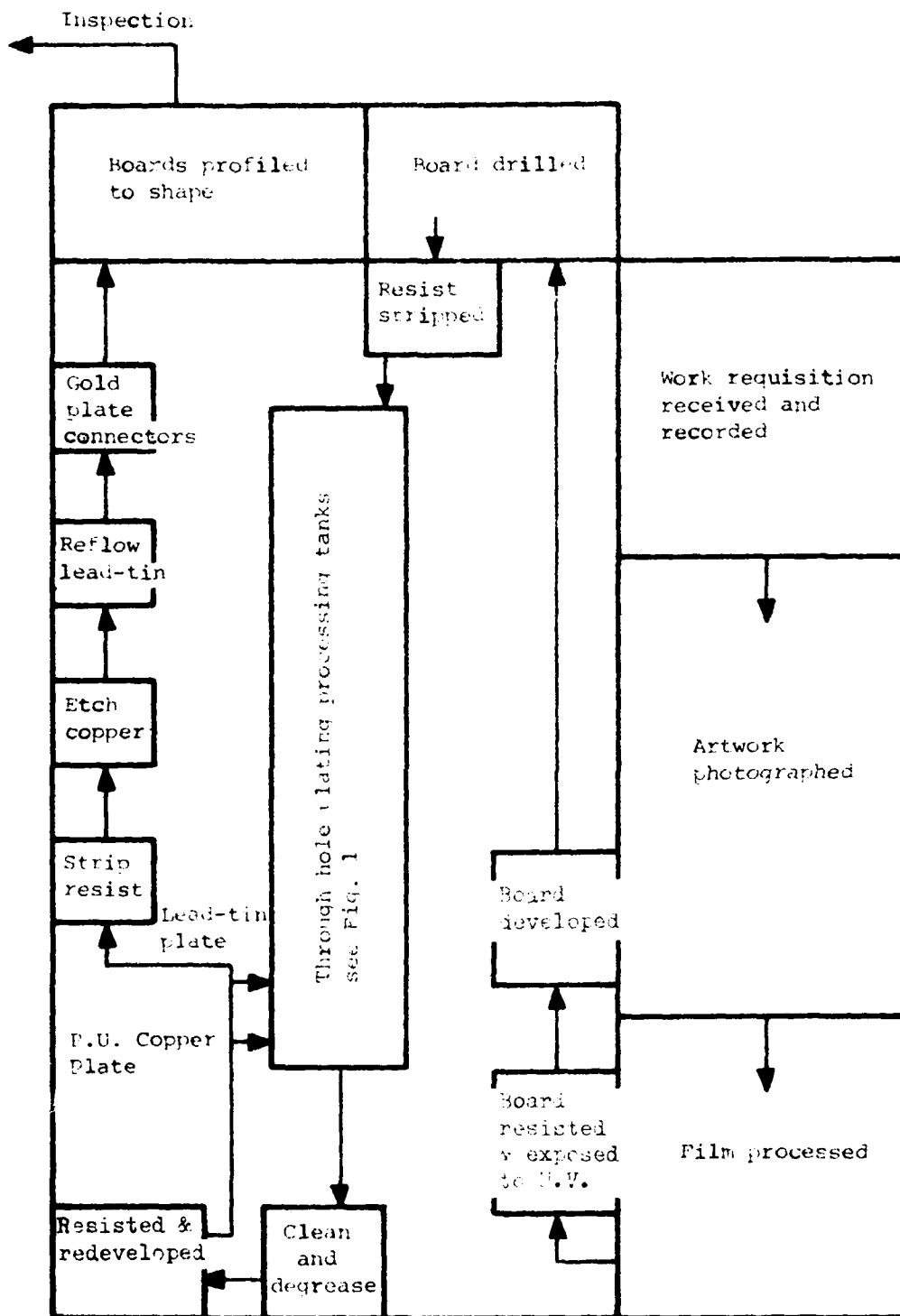


FIG.4 WORKSHOP LAYOUT FOR THROUGH HOLE PLATED P.C. BOARDS AT A.R.L.WORKSHOP

ANODISING

| | | | | | | | | | | | |
|-----------------------|-------|-------------------------|--|-------|-----------------------|---------------------------------------|-------|--------------------------|-------------------------------------|--|---------------------------------------|
| 1. Caustic soda | Rinse | 2. Nitric acid | 3. Sulphuric acid (anodising) | Rinse | 4. Dye | 4. Dye | Rinse | 4. Dye | 5. Caustic soda developing | Rinse | 6. Nitric desmut |
| | | | | | | | | | | | |
| M.U. etch 10. | Rinse | Lead-tin plate 9. | 10% Fluoroboric acid 8. | Rinse | Copper plate 7. | P.C.B. Electroless copper 6. | Rinse | 101 Conditioner 5. | P.C.B. Activator 4 | 10% H ₂ SO ₄ 2 | Enplate 1 A.D. 481 surface etch |

THROUGH HOLE PLATING

Processing bench lay-out designed to facilitate production by progressive steps to minimise chemical carry over and operator movement.

FIG.5 PROCESSING BENCH LAY-OUT



FIG.6 REAR
VIEW OF CAMERA

Neg. No.0410-16



FIG.7 CAMERA
FRONT AND CONSOLE

Neg. No.0410-17

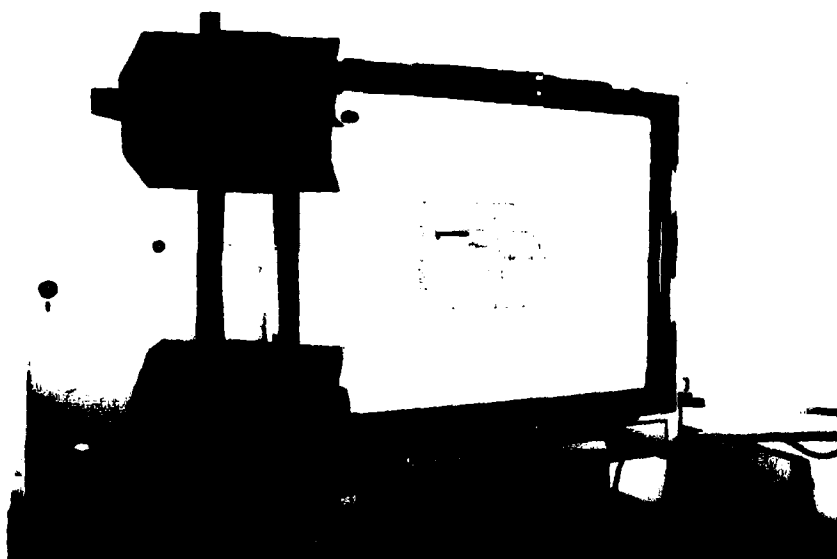


FIG.8 CAMERA
COPYBOARD

Neg. No.0410-13

DISTRIBUTION

COPY NO.

AUSTRALIA

Department of Defence

Central Office

| | |
|---|------|
| Chief Defence Scientist | 1 |
| Deputy Chief Defence Scientist | 2 |
| Superintendent, Science and Technology Programs | 3 |
| Australian Defence Scientific & Tech. Representative (UK) | - |
| Counsellor, Defence Science (USA) | - |
| Joint Intelligence Organisation | 4 |
| Defence Central Library | 5 |
| Document Exchange Centre, D.I.S.B. | 6-22 |
| DGAD (NCO) | 23 |

Aeronautical Research Laboratories

| | |
|--|----|
| Chief Superintendent | 24 |
| Library | 25 |
| Superintendent - Engineering Facilities Division | 26 |
| Divisional File - Engineering Facilities | 27 |
| Author: B.F. Porritt | 28 |
| P.H. Townshend | 29 |
| M. Watson | 30 |
| W.J. Keck | 31 |
| J. Harvey | 32 |
| N. Collins | 33 |
| J. Zosens | 34 |

Materials Research Laboratories

| | |
|---------|----|
| Library | 35 |
|---------|----|

Defence Research Centre, Salisbury

| | |
|---------|----|
| Library | 36 |
|---------|----|

Central Studies Establishment

| | |
|--------------------|----|
| Information Centre | 37 |
|--------------------|----|

Engineering Development Establishment

| | |
|---------|----|
| Library | 38 |
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RAN Research Laboratory

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